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ABSTRACT

The purpose of this study is to create a model that depicts the beliefs and other factors that influence secondary biology teachers when they incorporate newly acquired subject matter knowledge into the planning and instruction of an existing curriculum. Genetics content from Biology Update 1 and Secondary Biology Laboratory Curricula (SBLC) was used to create a case of contextual content. Two secondary biology teachers' perceptions of their planning and teaching were interviewed, and observed during their graduate courses and their classroom teaching of genetics. The model resulting from this study provides insights into the theoretical basis for increasing teachers' content knowledge understandings during and beyond undergraduate preparation. Research findings also indicate that scientists and science teacher educators should develop courses or workshops that assist inservice teachers in keeping their content knowledge relevant. Encouraging teachers to explore their beliefs about science and science teaching would create a better-informed and validated practice. (KHR)

Content Construction: How Content Becomes Curriculum in Secondary Science Classrooms

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Introduction and Purpose

Nearly every state in the country is raising the academic standards required for students. Consequently, this movement increases the expectations for teachers. Educators in many disciplines are being challenged to enhance their knowledge of subject matter and learn new teaching strategies. Over the past ten years or so, numerous calls have arisen for science teachers to deepen their content knowledge (Carnegie, 1986; Holmes Group, 1986; National Research Council, 1996; Shulman, 1987).

And now, in the new millennium, with the increasing demands upon science teachers to increase their knowledge in a science content area, it is necessary to study what factors influence if, and how, science teachers incorporate new content into their planning and instructional repertoire. When investigating teachers' incorporation of new content knowledge into their practice, studies have yet to be completed that integrate the three research areas of teacher beliefs, content determinants, and teacher thinking and planning with a focus on secondary teachers. The purpose of this study is to create a model that depicts the beliefs and other factors that influence secondary biology teachers when they incorporate newly acquired subject matter knowledge into the planning and instruction of an existing curriculum.

Theoretical Framework

Previous areas of research on teaching such as teacher beliefs, content determinants, and teacher thinking and planning provide a foundation for this study. A *brief* review of these research areas is provided.

Teacher beliefs have been identified as influencing both teacher planning and instruction (Clark and Peterson, 1986; Clark and Yinger, 1979). Thompson (1988) observed and interviewed three junior high mathematics teachers regarding their beliefs about mathematics and mathematics teaching, and how these beliefs relate to teaching. She found that teachers' beliefs about math and teaching math do shape their classroom behaviors. Brickhouse (1995) interviewed seven pre-college science teachers regarding their conceptions of the nature of science, their roles as teachers, and their students' roles as learners. This research suggests the presence of a link between teachers' beliefs about the nature of science and their classroom practice (Brickhouse, 1995). For example one teacher, who viewed theories as truths uncovered through experimentation, tended to have students learn only the content of scientific theories. Another teacher, who thought of theories as tools to solve problems, wanted students to use theories for solving problems. Teachers' beliefs about subject matter have also been found to influence day-to day decisions about what to teach, what to skip, and how much class time to devote to a particular topic (McDiarmid, Ball, and Anderson, 1989).

Research on factors that influence elementary mathematics teachers' decisions about what content to teach and how to teach is extensive (see Porter and others, 1986). This body of research examines the influence of five specific decisions teachers may make that can directly affect student achievement. These decisions involve determining how much time to allocate to a subject, what topics to teach, which students will be taught, timing and sequencing of the topics to be taught, and to what standard of achievement students will be held accountable (Porter et al., 1986).

Clark and Peterson (1986) provided a comprehensive review of research on teacher thinking and planning. Much of this research focused primarily on elementary school teachers, was conducted in a clinical setting, and tended to have a narrow focus of specific teacher thoughts. These "snapshots" of classroom events were limiting to their conclusions. Clark (1983) recommended that future research look at teacher planning in a naturalistic setting. Therefore, a need exists to describe the planning process of secondary in-service science teachers in their own environment, especially when attempting to incorporate new content into an existing curriculum.

Methodological Design

This study uses a design that is qualitative and naturalistic (Lincoln and Guba, 1985) in order to understand the context of and decisions made by teachers incorporating new content into their curriculum. The subjects were two secondary biology teachers, making this a multi-case study by design (Bogdan and Biklen, 1992). One middle school teacher (June) and one high school teacher (Natalie), simultaneously enrolled in two courses during the first summer session of a Masters Research Program for science teachers at a large southwestern university, were selected as subjects for a comparative study.

Because the purpose of this study is to create a model of curriculum influences as teachers incorporate new content knowledge into their teaching, the two summer courses, Biology Update 1 and Secondary Biology Laboratory Curricula (SBLC) provided a context and subject matter content for teachers to acquire new content knowledge. To trace the path of content from the two graduate courses into the teachers' classroom practice the field of content explored in the courses had to be narrowed. Genetics was a topic that was common to both courses and covered in very different ways. Biology Update 1 presented genetics at the cellular and molecular levels. The SBLC course explored various methods of teaching meiosis and mitosis. Genetics content from each course was used to create a case of contextual content.

Data were collected in the natural setting (graduate courses and teachers' classrooms) using a variety of qualitative methods including open-ended interviews and non-participant observations. Data consisted of informants' perceptions of their planning and teaching during in-depth interviews, and field observations during their graduate courses and their classroom teaching of genetics. Classroom documents such as quizzes, tests and worksheets also served as a source of qualitative data. Techniques similar to concept mapping (Novak & Gowin, 1984) were used to gather additional data for qualitative analysis for each teacher.

Qualitative data from each teacher was analyzed by organizing the data into topics, codes, and then categories based upon predetermined and emergent themes. The categories were analyzed further for patterns and then used to create a case for each teacher. Data from each teacher's concept mapping diagrams contributed to her case. Included and constructed in the case for each teacher was a personal model of curriculum influences. The cases and personal models were then combined and compared for similarities. The comparison of cases and models provided opportunity to generate the Model of Secondary Curriculum Influences that Affect Incorporating New Content into an Existing Curriculum.

The findings of this study are presented in a case study format that provides an in-depth holistic picture of the phenomenon within the natural contexts and settings. This format is useful because this study attempts to create a model that describes the beliefs and perceived factors that influence these secondary biology teachers' planning and teaching of newly acquired genetics content.

Results

The Case of Content

To trace the path of content from Biology Update 1 and Secondary Biology Laboratory Curriculum courses into the teachers' classroom practice, the field of content explored in the courses must be narrowed. Genetics was a topic that was common to both courses and covered in very different ways. Biology Update 1 presented genetics at the cellular and molecular levels. The Secondary Laboratory Curriculum course explored various methods of teaching mitosis. The genetics content covered in each course will be detailed in the following sections.

Biology Update 1

The purpose of Biology Update 1 was to bring the teachers up-to-date in recent scientific research developments and review subjects covered in the university's introductory biology course. This course provided background knowledge needed to understand most of the terminology and concepts presented in the science journal articles used in the course. Working in groups, the teachers analyzed and interpreted the data presented in the articles. This case of the content focused on topics that present information pertaining to genetics, and more specifically, Central Dogma (the process of converting the DNA message into a protein) and heredity. TABLE 1 outlines, the sequential and daily order that the genetics content was covered in Biology Update 1. The following section provides an overview of the daily context in which the content was introduced to the teachers.

The Context of Content: Biology Update 1. The Biology Update 1 course met for ten three hour class periods over five weeks. The course instructor had a Ph.D. in Biology, was an adjunct lecturer in the Molecular and Cellular Biology department, and taught and coordinated the introductory freshman biology courses. The vocabulary and grammar of molecular biology covered in the course were presented within the context of scientific journal articles on topics such as "Cladistics and Archaea: The Third Branch of Life", "Biochemical Pathways and One Gene Polypeptides: The Molecular Basis of Alkaptonuria", and "The War on Breast Cancer: BRCA1 and BRCA2." Because the genetics content was not presented in a sequential order, the content is discussed as it occurred within the context of the class. TABLE 1 illustrates the context of the content in Biology Update 1.

TABLE 1 Here

It was evident during class meetings that there were a group of four or five teachers who struggled with the content in the area of cellular and molecular biology. This is evidenced from personal accounts and statements made by several teachers during the class such as "I've never seen this before in my life!" and "This is giving me such a brain drain!" The teachers with a weaker biology background were expected to do extra studying outside of class time to be up-to-speed with the information being presented. Teachers brought in textbooks from their college courses or books they had purchased at the university's bookstore. They arranged study groups two to three times a week to try and stay current in the course. Some teachers tried to keep up with the class and others just tried to get through day by day.

One factor that may have complicated the content for several of the teachers was that the content was not presented in a sequential logical order--an order they would eventually be expected to teach. TABLE 1 illustrates the "haphazard" presentation of the content related to Central Dogma. This may have created some "content confusion" especially with the teachers who did not have strong background knowledge in the area to start.

A possible explanation for why the material was not presented in a sequential fashion, deals with the expectations and assumptions of the course instructor. On the third class meeting of the Biology Update 1 course, the instructor apologized for "leaping" into the structure and function of proteins and explained that in previous years she had reviewed with the class the function of proteins before advancing so quickly. She reassured the teachers that there was no reason to be "that familiar with amino acids" as they were expected to demonstrate the previous day. The instructor stressed that the course would "be a mix of a review from college and information from a deeper level of understanding." From the previous two days, she thought this group of people had a solid background and that is why she went forward so quickly. With that explanation she said, "We're going to plunge ahead today! Remember to ask questions if you need to do so." It was a rare occurrence though that a teacher would interrupt the class discussion to ask a question or say they didn't understand the material. Several of the teachers, including Natalie and June, commented throughout the course that the material covered was "over their heads."

Secondary Biology Laboratory Curricula

Ten teachers were enrolled in the SBLC course that met thirteen times over the five week summer session. Each class meeting lasted three hours. The purpose of the course was to introduce and study high school and middle school laboratory curriculum materials. The teachers conducted the activities and labs in order to study the science content, concepts, skills and processes presented in the curricula and to examine the teaching approach used in each activity or lab. The teachers also discussed the national recommendations for science education as a context for understanding the use of laboratory curricula in their teaching of biology. The class was co-taught by a recent graduate of the master's program who teaches high school biology and the coordinator of the MPGB who holds a Ph.D. in Biology.

The Context of the Content: SBLC. Of the thirteen class meetings, three days were spent discussing the topics of genetics and heredity. The teachers participated in activities that promoted conceptual understanding of the topics of genetics and heredity and simultaneously cautioned about using "tricks" while teaching genetics. The use of models and hands-on activities were encouraged.

Summary of the Content

The first two courses in the Master's Program curriculum were Biology Update 1 and the Secondary Biology Laboratory Curricula. Biology Update 1 provided detailed content on the topic of Central Dogma within the context of advanced science journal articles. The content presented in the course was not delivered in a sequential order and several teachers had difficulty keeping up with the content and the pace of the course. The SBLC provided content and pedagogical strategies associated with teaching mitosis and meiosis. The instructors advocated that secondary biology be taught for conceptual understanding while also being taught at the molecular level.

The Case of Natalie

Natalie's History

Natalie was born in California and took junior high science classes in California and remembers science as being fun and having "loved it". She describes her science classes as having very little structure and getting to "play with a lot of different stuff." It was in junior high that she first learned the word "hypothesis" and remembers it written on the chalkboard just sort of staring at her in big block letters: "HYPOTHESIS".

After her sophomore year in high school, Natalie and her family moved to Wyoming. This move was an unexpected one for Natalie who has just dyed her hair green. She said things were awkward at first but her hair returned to its normal red color and she eventually made friends in her new high school. While in high school she took several Biology courses. Solving Punnett squares was the only memorable science activity she remembers. Science didn't make sense to Natalie--she couldn't find the "science" in the class activities. She recalls looking at pond water under the microscope and pretending to see something in the pond water.

By the time Natalie was getting ready to graduate from high school, she had decided to go to a community college. She had always known that she would be going to college. It was one of those "unspoken" expectations of her parents. But, Natalie also had expectations for herself. She had many jobs during high school that did not require a college degree, but she did not see herself "flipping burgers" for the rest of her life. She saw college as "the way up" for her and her future.

Natalie's first choice for a major was photography. She attributed her decision to become a photography major to a fear and an intentional avoidance of mathematics. She said, "I never really did math well in high school so I just wanted to avoid that--I didn't have any continuity when I look back." Natalie referred to the several moves and the several schools she attended for junior and senior high school. By moving every couple of years she did not have the "continuity", as she says, across many subject matter disciplines.

As a photography major Natalie knew she would have to take a biology class. At first in the introductory biology class, she was experiencing the same difficulties she had in high school because the teacher only lectured. But, she was determined to study hard in college, especially when she did not understand. It was in this biology class that Natalie was once again, successful in science. She attributes her success to the course's teacher. Before each test he would post the questions and the answers so the students had only to memorize the information. Natalie recalled the experience, "I remember thinking, 'this is cheating, but this is great!' and I remember I did well and I was successful, and I loved it, and I learned. I was like 'Man! This is neat. I like science!'"

Natalie went on to take an anatomy and physiology course the next semester and decided to change her major to a science related field. She flipped through the college handbook, looked up science, and saw 'optometry' and thought, "I could be a doctor." So, she was now a pre-optometry major. Natalie transferred to the state's university as a science major. She took undergraduate biology courses such as: biology, anatomy and physiology, genetics, plant anatomy, plant physiology, ecology, animal behavior and microbiology.

It was during the last few semesters at the university that Natalie realized she really didn't have the resources or the grades to get into a medical school. It was then she realized that she had always wanted to teach--she could teach science and make a difference. When she pictured herself teaching, it was at the elementary school level. But, by the time she decided she was going to be a teacher she was so close to graduating with a bachelors degree in biology and opted for the secondary certification track instead of taking the additional requirements for an elementary education certification.

After graduation Natalie enrolled in courses for her secondary certification and was in classes up until the time of her student teaching. She remembered one field experience when she had to teach junior high for one day. This was a strange experience for her--the bells and switching classes. She had not been in a classroom since she graduated from high school.

As part of her secondary certification, Natalie had to take several other biology classes. She enjoyed the "Plant's, Agriculture, and Civilization" course and even uses a lab from the course in her own teaching. Evolution was a required course for certification as well. This course, and the course instructor especially, made a huge impact on Natalie as a student, as a future teacher, and on her personal self-esteem. She received a 30% on the first paper in the course. This was a huge blow to her; after all, she had graduated with a degree in Biology. She thought, "How did I get 30%?" She knew it wasn't "A" work, but she had written many papers before and not received as low a grade. For the first time in her college career, she went to a teacher's office. What she heard in that office almost destroyed her, but made her confront a part of her she had never let surface. The instructor told Natalie that she couldn't write. "What do you mean I can't write?" she asked almost hysterically. "Well, you just can't write" was the instructor's response. Natalie described her feelings and the events that followed:

> So I got really upset. I don't know how to ask for help. I've never been criticized to this extent before, I don't know what to think about it, and secretly, I believe she's right. I've been faking it all this time and she's the one who finally found out. I believed her in a way. That's the first time I ever admitted that out loud, even to myself....I couldn't write and I'd been fooling everybody all along, everybody but her....She didn't encourage me at all, didn't leave me with any hope. Of course, if I knew I could have written I could have found my own hope....I asked her at that moment if she would sign the drop slip, but I don't remember getting a positive response. I never went back. I took an "F."

This story though creates doubt in Natalie's mind that she ever learned evolution.

The evolution instructor had a definite negative impact on Natalie, but many of her other college science instructors made positive impacts as well. There was the introductory biology teacher at the community college that posted the answers to the test questions. Natalie said he made her feel successful before she really deserved to. Even in high school, she never had felt successful. She was more interested in boys and was paying only "half attention" in class, or never had "good teachers". Natalie felt like she was "making it by", but never successfully or to her fullest potential. The "A" she received in that first college biology class renewed those feelings about science she had in seventh grade--feelings she had forgotten.

Natalie remembered her college chemistry instructor teaching the class a trick to remember whether scientific notation was negative or positive. Her physics teacher assigned 'challenge' problems every week that she "lived for" because she could show her engineer boyfriend how smart she was by solving the problems. The graduate teaching assistant in her plant physiology course was memorable as well. It was Natalie's first semester at the university and was doing well in the class because she could study and easily repeat the information. But, when it came time to design a research project in the lab portion of the class Natalie did not have the first clue on how to begin. The TA thought of her project for her, told her exactly how to do it, and Natalie did exactly what he said. She said she still feels like she "faked it" because they both knew that she didn't know what she was doing. This experience was what Natalie hated about science research and said she does not thrive on feeling uncomfortable about her abilities.

Natalie was 30 years old and had been teaching high school biology for four years in a rural border town community in the southwest. She started her fifth year of teaching at the secondary level and could no longer see herself teaching at a lower level. In the past she has taught general biology, life science, and most recently has added honors biology to her teaching load. This year, Natalie taught four sections of general biology, one section of honors biology, and took on the school's decathlon team for a sixth-fifths teaching load at the high school. In addition to her high school position, she also taught two introductory biology courses, four nights a week, at the local community college. Having taught biology at four different levels Natalie doesn't think there is a big difference in what she teaches. She says, "My expectations of the students are different, but what I teach them, the way I lecture to them and what I tell them, [are] pretty much the same."

For the previous three summers, Natalie had engaged in various professional development programs for science teachers. She sought out these opportunities to do something "fun" that would also benefit her in some way. Before taking classes in the MPGB, she participated in the University of Arizona Medical Ignorance Program and did research at the National Labs in Los Alamos, New Mexico. Both of these programs devoted time to discussing how the teachers were going to change their classroom teaching as a result of attending the summer programs and doing science research. Natalie described what she learned from the two programs:

> What I learned in those programs is how to do a tissue culture and how to stain cells and big deal. Nothing exactly I'm going to take back. But, what I learned was what scientists actually do and before I didn't know. I had the white coat picture and even though I had a bachelor's degree in biology, I didn't know what they did. I had never been in a lab before. So, I brought back from my experience, "this is what they actually do" and a lot of stories.

In many areas of her life, Natalie had low self-esteem, and she recognized this fact. By participating in professional development programs that focus on science, Natalie felt more confident. She said she participated in the programs because she was looking for confidence and recognition. She considered her three summer experiences as "three feathers" which gave her a stature among her peers. She explained:

> They think of me differently. Whether I actually do anything different in the class or not, I get more recognition, and get different types of students. That's probably why I got the honors biology classes because I did some of these programs.

Natalie's past experiences in science and her recent research experiences influenced her beliefs.

Natalie's Beliefs

Natalie's beliefs about science, learning and teaching science are very strong and interwoven. The table "The Relationship Between Natalie's Beliefs" was created to outline these beliefs and illustrate the relationship that existed between her beliefs (see Table 2).

TABLE 2 Here

Natalie's Teaching of Genetics

> I consider myself doing genetics once I start replication all the way through phenotype and Mendel's work, all the way through human inheritance, sex-linked inheritance, showing them how things happen and with mitosis and meiosis in there too. They really work well after you do replication, transcription, and translation.

Table 3 chronologically recounts Natalie's teaching of genetics during the semester following the summer MS program courses. At the time of this study, Natalie was teaching genetics to her general biology class and her community college class. Included in this account is a summary of major concepts and supporting details or definitions mentioned in her high school life science class.

Table 3 Here

Natalie's Curriculum Influences

District guidelines existed for Natalie's content area of biology, but were viewed as "suggestions" and were not mandated by her administration. Therefore, Natalie had ultimate control over what was taught in her biology classes. Many factors existed which influenced Natalie when faced with incorporating new content knowledge, from the two MPGB courses, into her teaching. These factors, labeled in discreet terms, were highly interrelated and are diagramed in FIGURE 1. The diagram is somewhat hierarchical with "Course Content (MPGB)" at the top, "Natalie's Genetics Teaching" at the bottom, and the influencing factors in between acting as "filters" of the content. The purpose of this section is to describe the factors and their relationship to each other and how they acted as filters of the biology content Natalie was exposed to in the two courses.

Figure 1 Here

View of Self. Natalie's beliefs about herself and her abilities had the greatest influence on her teaching and the other influencing factors. Natalie admittedly, had very low self-esteem in several areas of her life. She had repeatedly stated that she felt like she was "faking it" in her science courses in high school and college -- she pretended to see organisms in the pond water, she let the plant physiology teaching assistant design her experiment, and she felt "busted" about her writing abilities in the Evolution course. Natalie never developed a sense of confidence or success in her science classes until a college instructor allowed her to "cheat" on tests. Recently, Natalie participated in science and science research related professional development activities to gain a feeling of confidence in her abilities. She said that even though these programs may not change her teaching, they still change who she is and her self-confidence.

Natalie's View of Herself Influenced Her Other Beliefs. Natalie's beliefs about science, beliefs about learning, and beliefs about teaching were all greatly influenced by her view of herself and her abilities. Natalie believed that science and science research should only focus on "the big picture" and not focus on details. Natalie also defined science as "the world" and believed that learning meant using "real words." Her own feelings of inadequacy in the content area fostered these beliefs and directly related to a simplification of content, an absence of detail in her own teaching, and an incorporation of stories and analogies to make meaningful connections. For example, Natalie did not teach her students about the enzymes involved in replication, transcription, and translation but was able to use several analogies when describing the processes.

Natalie's view of herself as a learner impacted the teaching strategies and methods of presentation in her teaching. Natalie referred to herself as a visual learner and used overhead illustrations, and drawings and writings on the board in her teaching to help simplify the concepts for her students. She also required her students to take notes and write down the information she put on the board. She was teaching the way she wished she had been taught--the way she had to reteach herself.

Relationship between New Content, Beliefs, and Teaching. The content courses had a greater impact on Natalie's "pedagogical" thinking rather than her "content" thinking. The courses provided Natalie a renewed student perspective and several strategies to use in her teaching that were consistent with her beliefs. Her focus changed from teacher oriented roles and duties to student oriented roles and concerns. The detailed science content and suggestions presented in the courses was not consistent with her beliefs and thus did not have a great impact on Natalie's knowledge.

Natalie incorporated content from the courses that was consistent with her beliefs. For example, the instructors of the SBLC course encouraged the teachers to teach conceptually and not use the names of the phases when teaching mitosis. Natalie agreed with this practice and did not incorporate any "advanced" terminology when she taught mitosis and meiosis. Philosophically, this suggestion was compatible with Natalie's beliefs about science, learning, and teaching, so the strategy "filtered" through to her teaching of genetics. For example, she did not use the term "spindle fiber"--instead, she called it a "fishing wire." By using analogies in her teaching, Natalie also demonstrated her grasp and understanding of the content area and was able to represent the content to her students in a meaningful way.

Also, Natalie did not incorporate content that was incongruent to her belief systems. For example, in the same course, the SBLC instructors said that biology should be discussed at a molecular level, but Natalie did not incorporate this suggestion into her teaching, or into her content knowledge base. She believed that molecular topics are too obscure and not worthy of study because they are on too small of a scale. This, in part, was one reason Natalie did not remember the differences between the different types of RNA. Those details did not fit into her simplified scheme of the "big picture" and therefore did not filter through to her content knowledge or her teaching.

Natalie's Beliefs about Science Influence Her Teaching. Natalie's beliefs about science related directly to her teaching for broad concepts and avoiding details. Even though she said she doesn't "hold their hands", she still simplified the genetics content for her students. For example, Natalie did not mention the function and structure of amino acids and proteins--information that was presented in Biology Update 1. Natalie also did not encourage students to use scientific terminology. Rather, she made connections to students' prior knowledge and encouraged them to do the same by using words from the "real world." This act was somewhat contradictory to her statement that she viewed science as "the world." For Natalie, scientific terms and definitions, especially those at the molecular level, did not fit into the "real world."

Natalie also believed that science had an inherent order and logic. According to Natalie, if something was logical it could be simplified into steps. This belief is evidenced by her use of "tricks" to simplify the genetics content for her students. For example, she used "tricks" such as Punnett squares to solve monohybrid crosses and the "foil" method to separate alleles for the independent assortment of gametes during meiosis.

Natalie's Beliefs about Learning and Confidence. Natalie believed one can learn science if they have confidence. She tried to teach her students "tricks" to remember scientific information so they can be successful and have confidence to learn. Recall though, that the SBLC instructors suggested the teachers not use "tricks" when teaching students about Punnett squares. This suggestion was not congruent to Natalie's beliefs about teaching and learning. The teaching of tricks was reminiscent of her experiences as a student--learning tricks from her teachers or teaching herself ways to remember the information. Knowing tricks gave Natalie confidence in her science abilities. This is not to say that Natalie thought her students did not have the ability to learn on their own. But, she transferred many of her own learning habits on to her students. She realized that some students did have natural talent, but that many of them would not go on in science. She wanted to provide them to the tools "to figure it out."

Parroting was another tool Natalie used as a learner and as a teacher. By repeating information over and over, Natalie believed her students could learn the content--by rote. The students needed some type of strategy because Natalie believed they had difficulties making connections to their own prior knowledge. But, Natalie had doubts about the effectiveness of the parroting in developing an understanding of science concepts. She made references to parroting and her own knowledge and understanding of science and how she did not always understand what she said when parroting an instructor.

Natalie's Planning was Affected by Her Current Responsibilities and Time Constraints. Natalie's ability to incorporate new content into her teaching was ultimately limited by her busy schedule and time constraints. Teaching six hours a day at the high school and four days a week at the community college had put definite boundaries on Natalie's time to spend planning. She also had two new preps to teach which added to the mix. Natalie did not have time to revisit the detailed content she was exposed to in the summer courses. Natalie though, was able to glean some of the broader concepts that were covered in the summer courses--those that coincided with her established beliefs.

Summary

Natalie's incorporation of new content was influenced by her self-esteem, her beliefs about science, her beliefs about teaching and learning, her own content knowledge and the time constraints placed upon her by teaching an overloaded schedule at the high school and teaching four nights a week at the community college.

Of these factors, Natalie's self esteem had the greatest impact on the development of her beliefs. Gaining confidence was important to Natalie for several reasons. She felt that she had "faked" her science content knowledge throughout high school and college. For Natalie, having confidence meant she could learn science, and, if she could learn science her confidence would increase. Despite her accomplishments, Natalie was still doubtful about her abilities and her science content knowledge.

Natalie's doubts about herself as a learner influenced her developing beliefs about science. She focused only on broad concepts and belittled details. These beliefs about science influenced her beliefs about teaching and learning, as well as her own knowledge. By viewing science as logical and orderly, Natalie could justify reducing and simplifying content into a series of steps or tricks. She stated that learning was not recalling information immediately, but knowing where to look for the information. This belief about learning supported her beliefs about science and influenced her views about what was important to know about science. Because details were not important and she did not have a need to know details, Natalie did not learn detailed content from the summer courses. There was one other factor which influenced what content was to be incorporated into her teaching. Natalie's teaching load and other time constraints had the greatest impact on her time to revisit the information presented in the summer courses. Therefore, the only content that "filtered through" was that which was incorporated into her knowledge base because it was congruent to her existing system of beliefs.

The Case of June

Elements of June's case, as represented in her model of curriculum influences, are provided in this section.

June's Past Experiences and Her Confidence

June was a twenty-five year old native resident of Arizona and had lived in the Phoenix area for most of her life. She was in her fifth year of teaching, her third at the middle school level. She doesn't remember taking science in grade school other than a Health class and her first memories of formal science classes are from middle school. June recalled having to memorize the elements and their symbols in seventh grade. In eighth grade she remembered dissecting a frog and looking at and classifying rocks. June took Introductory Biology in ninth grade and liked it very much. She described herself, though, as "lazy" and having "never studied for the class", and doing "just enough to get by." Looking back, June was sad about her lackadaisical attitude and wished she had applied herself. She felt like she cheated herself and wondered how her life would be different if she had only studied.

But, science was not always a formal experience for June. Her father had a very big impact on her curiosity while she was growing up. She described him as “always very questioning.” He would encourage her to explore the world on their frequent outings. On some days, June would play “hooky” from school and go fishing with her father. Science became an outdoor activity for June--something fun. She described their adventures:

> I learned about things I was interested in and a lot of it was outdoor stuff--about animals. We collected poisonous black widow spiders and we’d watch their mating and eating behaviors. We’d have little black widow battles. It was always very fascinating to me and my dad was always very excited about it so that sort of instilled an interest in me, but it didn’t feel like academics. It was never something I had to learn. It was fun stuff!

June would occasionally accompany her father when he worked nights in the emergency room--he was a medical technician at a local hospital. June would see him working with sophisticated machinery and asked a lot of questions of her father while he was working. June did not consider these science experiences to be very academic either.

She could really relate to her father when it came to science. She said, “It’s interesting because he didn’t do very well in the science classes. But, he was always interested in the stuff and that’s how I was. I was never really good at it, but I always thought it was pretty cool.”

June amassed 30 credit hours in biology toward her secondary education degree at a local liberal arts college. She took content courses such as desert ecosystems, genetics, nutrition, introductory biology, botany, zoology, anatomy and physiology, and microbiology. June said that three of the biology courses (biology, desert ecosystems, and zoology) were taken as independent study courses in which she had certain objectives to meet but never attended a formal lecture or lab. And although her background was varied, June pointed out that she never had a cellular biology or biochemistry class in college.

Since becoming a teacher June usually spent her summers teaching science in summer school. Taking courses in the MS program was a definite change for June. Not only were these the first graduate courses she had taken, June also had to move 100 miles away from home for the summer program. This was the first time she had been out of town on her own. June did not have a lot of confidence in herself as a result of her college education, but she said, by taking classes in the MS program her confidence was increasing:

> I'm starting to feel that I'm approaching the caliber of what most biology teachers have as far as education. At the beginning of the summer I was not very confident because I did kind of take the easy route as far as school. If I would have gone to [the large local university] I would have been there a lot longer, I would have had to take a lot more classes. . . . But my confidence really has improved. When I came back from school this summer, I felt like the world was out there! And I can have what ever I want and I can do it!

June did not describe herself as a confident person, but attributed her classroom presence to being "a really good actress." June went back to her school after the summer in the MA program with an increase in confidence. She told many of her colleagues how difficult the program was and how hard she had worked. June didn't feel like her peers looked at her differently because, she thought, they had more confidence in her than she had in herself. But now, June felt confident that she knew more science than her seventh grade students. This was a concern for her because she had often been "stumped" by questions her seventh graders have asked in class. June also shared her summer experiences with her students' parents on open house night--giving her a feeling of credibility. She said, "They are very supportive and really want to know what is going on. I think it helps when they realize this is someone who knows what they're doing and they're more apt to have faith in me."

June's Beliefs

June's beliefs about science, learning and teaching science are very strong and interwoven. The table "The Relationship Between June's Beliefs" was created to outline these beliefs and illustrate the relationship that existed between her beliefs (see TABLE 4).

TABLE 4 Here

June's Teaching of Genetics

> I've never done much on genetics because I've never really felt comfortable with it. But, after both classes, I'm not an expert, but at least I have a clue and can teach it at the seventh grade level and have enough confidence and knowledge about it to do that much.

This was the first in her five years of teaching that June taught topics in genetics. In fact, June preferred to call what she was teaching "heredity" rather than "genetics." TABLE 5 chronologically recounts June's teaching of heredity during the semester following the summer MS program courses. Included in this account is a summary of major concepts and supporting details or definitions mentioned in her seventh grade life science class. Note the topics and concepts were presented in an order that was not conducive for student development of a conceptual understanding of genetics.

TABLE 5 Here

June's Curriculum Influences

June had the flexibility to decide what to teach in her seventh grade life science class. Many factors existed which influenced June when faced with incorporating new content, from the two MS program courses, into her teaching. These factors, labeled in discrete terms, were mostly linear in their relationship and are diagramed in FIGURE 2. The diagram is hierarchical with "Course Content (MS program)" at the top, "June's Genetics Teaching" at the bottom, and the influencing factors in between acting as "filters" of the content. The purpose of this section is to describe the factors and their relationship to each other and how they acted as filters of the biology content June was exposed to in the two courses.

FIGURE 2 Here

June's Knowledge as a Primary Influence. June's content knowledge was the limiting factor for the possibility of any content from the summer courses to be incorporated into her teaching. Although June felt like she had learned a lot in the summer classes, she admitted that the Biology Update 1 course was especially hard for her. She talked about her difficulties with the course:

> I've never taken a cellular biology class. So a lot of the stuff was stuff that either I didn't remember or stuff that I'd never been exposed to. I always felt behind. I just hadn't taken the initiative to really, when there was something I didn't understand -- I didn't go out of my way to look it up. I could've done that and I should've done that, but I didn't. . . . I'm not going to be a cellular biologist or be working in that area of research so I couldn't see me using that field as part of my thesis. I didn't see a whole lot of relevance.

June admitted to not applying herself and doing the extra work for the Biology Update 1 class, which greatly diminished the content she could take back to her students. June's lack of application was influenced by her lack of self-esteem about her own content background and her beliefs about her own learning.

June did not have a great deal of confidence in her content knowledge and her abilities. She took the "easy route" in achieving her teaching certificate and felt that she did not have the same level of preparation as other science teachers. Her perceived lack of preparation did not enable June to form a coherent and conceptual view of science and likewise, this affected her content knowledge. Prior to the summer courses, June described herself as having a breadth of knowledge about biology rather than a depth of knowledge. She also felt that for certain subjects she did not have adequate knowledge or resources that stressed important information. During the previous year June had not taught the students about the differences between prokaryotic and eukaryotic organisms. She explained:

> I don't think I had enough information about it to teach my students. I never really thought about the fact they don't all have nuclei. Part of it is within the textbooks and resources that I use don't make a big deal about it. So, it never clicked to me that this is real important. I didn't [teach it] in high school either.

June did not want to get "too in-depth" when teaching science content. June felt that seventh grade students needed a survey of the content--something she was comfortable with as well. June was asked what helped her to make decisions about the content she teaches and she responded:

> Well, it is partially my comfort level. I mean, I've never had cellular biology. And from [the Biology Update] class, I'm thinking back to transcription and translation and I'm thinking, which one is which again? So, obviously before teaching anything new, I go over it and make sure I feel comfortable with it. Again, I think it is a need to know sort of thing and there is so much that they need to know that I think is more critical at this point.

The lack of academic preparation also influenced her beliefs about her own learning. June was asked, "how do you learn best?" and her response was that she asked other people or looked for the answers in books. But, she also stated that she rarely took the initiative to look for answers and only did if it was a question someone had asked of her. For June, the question or the content had to be relevant to her and her needs if she was going to take the time to look it up or learn it. This is evidenced in June's comments about applying herself in the Biology Update 1 course. She knew she wasn't going to be a cellular biologist, so the detailed content did not have relevance or create an interest in her to learn.

June's Knowledge and Beliefs about Learning and Teaching. June had beliefs about learning that resulted from her previous experiences as a middle school teacher. June realized that her students had a variety of learning styles and believed that it was her responsibility as a teacher, and a knower of the content, to present the information in a different ways. To accomplish this task, June believed that a teacher had to have a greater understanding of the content than her students did. It was this factor that had kept June from teaching genetics previously. She did not feel comfortable with her own knowledge of the content and therefore skipped the topic.

June said she still was not totally comfortable teaching genetics after taking the MS program courses. Her discomfort with content was responsible, in part, for a lack of detail and coherency in her teaching (see Table 2). June also felt that her students did not need to learn detailed science information in seventh grade because they will be exposed to that in high school. Rather, she felt students in the seventh grade need a survey of biology in which they learn broad concepts that could be built upon later. She also simplified the science content for the students because "there's too much and it's too overwhelming." Science was challenging enough for her students even without the details. June believed, though, that her students could learn detailed content--it would just take them a very long time to learn it and, June did not want to take the time. Therefore, June felt limited in her teaching by her own content knowledge and the ability of her students to learn content quickly. In seeming contradiction, though, June states she was not concerned by these limitations in her teaching.

The Relationship between Science, Learning, and Students. June's beliefs about science were dependent upon her past experiences with her father, as well as the amalgam of courses she took in college. June's beliefs about learning stem partially from her own experiences as a learner, but were mainly rooted in her experiences with students.

As a student, June did not have an opportunity to make connections between different biology classes in order to develop a sense of the nature of science. She was never aware, or made aware of, content and science concepts that were important to teach. For example, she did not know it was important to distinguish between prokaryotic and eukaryotic organisms based on the presence of a nucleus--this as well, may be a consequence of her content knowledge. As a result, she held on to beliefs from her childhood--science is fun; and beliefs from her college courses--science is rigorous. These contradictory beliefs worked nicely for June as a middle school teacher.

During the interviews, June described her role as a teacher as "a PR person for the field of science." A big part of her job consisted of creating an interest in science and making it fun for her students. June made science fun by having students be creative and use their artistic abilities. She talked about an activity she had done in the past and planned to complete during the current school year:

> Hopefully, we'll have time to dissect a flower this year too, but I have them build one. It is a really tough task for them. They have to see how it is all put together before they can actually build it. They build these big posters or dioramas and they have a choice about what they do. So, instead of labeling a picture of a flower a whole bunch of times and memorizing where the parts are, they build one out of different materials.

June said this idea was one she was interested in because it would be fun for the kids, and it would be a new activity--something they had never done before.

Making science fun was not June's sole concern in teaching science. June felt that although science can be fun she did not want that to be the only way her students thought of science. June voiced her views on her "other" role as a science teacher, "I want to teach them skills and how to think. . . . And part of that is making it difficult for them because they need to find it challenging."

Many of June's beliefs about learning were influenced not only by her personal beliefs about science but also by her experience as a middle school teacher. Many of June's beliefs about learning were directly related to her students and their abilities. June's belief that science is rigorous coincided with her belief that students need to have structure when learning challenging content. June was concerned about giving her students a realistic perspective about science. She said:

> I want to give them an exciting view of science but I also want it to be realistic and they need to know if they are getting into a science related field it is not all pouring things into test tubes and seeing what bubbles over. There's a lot more to it, a lot more critical thinking, a lot more research, a lot more reading and writing. They need to know how to communicate what they have learned.

She talked a great deal about providing a balance between structure and fun for students when they learned science. June also believed that science should be fun, so she simplified the science content for her students and incorporated many activities that forced students to be creative. This simplification and lack of detail also corresponded to her belief that learning science was important for the students and their future needs. By providing a survey of new and interesting science content that was relevant to students and their lives, June hoped to create an interest in science for her students, not only for their high school courses, but for the possibility they may become future scientists.

June's Beliefs about Teaching Science and Her Classroom Limitations: The Final Filters. June's content knowledge and beliefs about science and learning greatly influenced her beliefs about teaching science. Her beliefs and the physical classroom constraints with which she worked motivated June's classroom practice.

June believed that science was rigorous and structured and therefore, provided opportunities for students to experience the structure of science. June had the students use lecture outlines when taking notes in class. These outlines were "skeletons" and corresponded to the class text. June liked this type of structure for the students, not only to help their understanding but also to help her keep track of their note-taking abilities. Students were also aware of the procedures of taking notes and finding notes if they were absent. Note taking became a familiar task for the students and also saved June time from dealing with the absences and missing notes.

Another way that June made science rigorous and challenging for her students was by incorporating a variety of novel tasks. The genetics activities she used were different enough from one another to challenge the students and keep the content rigorous. June also incorporated other skills such as mathematics, following procedures, data collection, and data analysis into the activities to challenge students and provide them with a "realistic view" of science and all the hard work it entails.

In addition to making science challenging and difficult, these tasks also fulfilled June's other requirement that science be fun and exciting. The tasks and activities June chose during her heredity unit allowed students to tap into their creativity and not be limited by the confines of rules and procedures. June believed that many of the activities made science interesting for students because they were "new things" so the students wouldn't be bored. The activities were also "hands-on" and required the students to flip a coin or draw and color a picture--the students were always active during these times.

June also tried to create an interest in science and find relevance for the students by using analogies and telling stories about her experiences in science. By likening the supercoiling of DNA to the wires in a phone cord, June was able to relay the complexity of DNA's structure to her students while showing them the cord from the phone in her classroom. June also told her students about her experiences from another course she took in the MS program in which she isolated and purified onion DNA. Now that June had "more content knowledge", she said she still may not teach that information to her students. She thought the "extra" information would be more valuable and interesting for the students if it was "added in" as part of a story. June liked the idea of sharing her experiences with her students. She described telling stories that "pop into your head" and not holding students accountable for the information. June believed this made science more interesting and relevant for her students.

To keep science fun and exciting, June did not hold students accountable for detailed information she happened to present. For example, she mentioned the term "nitrogenous bases" and quickly said, "you don't have to know that!" June also simplified the genetics content because it was "too obscure" and she worried it may bore students and "turn them off to science."

It was important to June that she taught students information they were interested in and content she knew they would need for high school. She recalled her own high school biology experience and how it applied to her teaching:

> When I got to high school, I felt like everyone else knew that from seventh grade and I haven't even heard of anything and was really lost. I don't want them to feel really lost when they get there. I want them to have some basics. . . .

June, the "PR" person for biology, felt she had a responsibility to teach students things they had not done in previous science classes. June communicated with the sixth grade science teacher so she was not "beating a dead horse" and found out that many of the things that were new for the students were also topics she liked to teach:

> They've done a lot of animals in sixth grade and I do more microbiology. They don't do much plants and I do the whole botany area. So, I'm trying to expose them to things they haven't seen and then get a little more in depth with stuff they have learned.

June's beliefs about teaching science were influenced by her content knowledge, her beliefs about science, and her beliefs about learning and her student's abilities. But these were not the sole influences June had to consider when incorporating new content into her teaching. June categorized the other influencing factors as "Classroom Stuff" and it was these factors that were the final filter of what was taught in June's life science classes.

June listed and described many limitations to teaching science effectively. When planning activities, June also took into consideration the students' reading level, their ability to grasp abstract ideas, and how active they would be during the event. June had 35 students in her largest class and from a management perspective she could not give students the freedom during lab activities that she had hoped. June mentioned her students' attention span limitations that often distracted the class from the topic at hand. The supplies she had available for labs and demonstrations also limited June. She learned several techniques to extract DNA but was unable to perform these for the class because of a lack of technology and equipment available at her school. And, sharing available materials with other teachers was an organizational nightmare. Time was an additional factor that limited June's teaching. She said:

> I have such short classes it is very difficult. That's why the microscope lab took more than two weeks to do. I have 40 minutes at a time and by the time you recap the stuff they had questions about the day before. . . Then that takes 10 minutes so they only have 25 minutes left to work because you got to clean up when you're done.

Despite these obstacles, June described her goal of teaching science to her seventh graders:

> What I really should be doing is getting them excited about science. More than anything, if they have a positive experience with me and they learn something and feel good about it, they'll be much more likely to continue on.

These "classroom stuff" limitations are factors for every teacher when teaching any content--new or familiar. And although these did not have a great effect on the incorporation of new content into June's teaching, they were still the final factors she had to consider while teaching her new heredity unit.

Summary

June's incorporation of new content into her teaching was influenced by her own content knowledge, her beliefs about science, her beliefs about learning, her beliefs about teaching science, and limiting factors that June described as "Classroom Stuff." Of these influences, June's content knowledge was the primary and most limiting filter of the new content.

June's content knowledge was affected by her lack of self-confidence, her beliefs about science from childhood, and her beliefs about her own learning. All of these experiences allowed June to incorporate into her own knowledge base only content that she found relevant to her own needs as a middle school science teacher. Although June had hopes of one day teaching at a community college, she knew she was not going to be a cellular biologist. Therefore, she ignored the details presented in the MA program coursework and allowed only content which was relevant to her and her students to filter through.

June held on to the beliefs about science that she had constructed as a child and as a college student. At no time in her undergraduate teacher education did June have the opportunity to develop an understanding of the nature of science. She still viewed science as both rigorous and fun and provided opportunities and activities for her students that reflected her conflicting beliefs. After the summer courses, she developed a better sense of what was important to teach her students. During the following school year June incorporated genetics content into her teaching for the first time in her career. Although she was not comfortable with her content knowledge on the topic, she attempted to teach it to her students and could justify her simplification of the content.

June was always teaching to her students-- she always took their abilities and interests into consideration when teaching. She tried to present the content in a way they would understand. She also wanted to cover topics they would find interesting and would be useful for their high school biology classes. She hoped they would find science interesting and pursue it later in life. Middle school teaching fit well for June because of her knowledge, her beliefs, and her concern for students and their future.

Influences in Constructing Content

The purpose of this study is to construct a model that depicts the beliefs and other factors that influence two secondary biology teachers as they incorporate newly acquired subject-matter knowledge into their planning and instruction. The following section takes into account the three cases presented earlier --the case of content, the case of Natalie, and the case of June. A comparison between the two teachers beliefs and curriculum influences will be presented first and the case of content as influenced by the teachers' beliefs and curriculum influences will be presented second. Finally a model of secondary curriculum influences is proposed which considers the cases--combined.

Natalie and June Compared

Natalie and June shared many similar beliefs about science, learning, and teaching science. There were also common themes stranded through their beliefs that affected their planning and teaching. A summary of their shared beliefs can be found in TABLE 6.

TABLE 6 Here

Natalie and June's Past Science Experiences. Natalie and June's past experiences in science had a great impact on many of their beliefs and actions. Both teachers shared common experiences before entering and during their respective teacher education programs. And, their past experiences filtered through to their beliefs about science.

Upon graduating from high school, Natalie and June each entered a community college before transferring to four-year institution. Both also had declared a major in a health related profession--Natalie was in pre-optometry and June was in nursing. Due to some event, whether it be taking a test for professions, or realizing the chosen major was not realistic, both women changed their majors to secondary science education.

As part of their secondary science education curriculums, Natalie and June took a variety of biology courses. However, the courses and the content remained very separate and discreet topics in the minds of the prospective teachers. Neither had the opportunity to make connections across biology topics because they randomly took courses without a coherent plan of study. This was true for Natalie even from her childhood moving from school to school and town to town. And in her post-baccalaureate career, she had to take biology courses out of sequence because of her biology major. For June, she did not have the opportunity to dialogue with other students or make connections because several of her biology courses were independent studies. June also mentioned that she took the "easy way" when getting her degree and did not feel prepared as a science teacher. All of these past experiences of both Natalie and June greatly impacted their self-confidence and other beliefs--most notably, their beliefs about science.

The similarities between Natalie and June's beliefs about science have been presented earlier. What were not discussed were the differences between their beliefs. The main difference between Natalie and June's beliefs about science was the origin of the beliefs. Natalie's beliefs about science originated with her struggles with science content in college. Once she experienced success in science she was able to enjoy science and see the logic and order that underlies many science concepts. Her difficult experiences in college, her lack of confidence, as well as her recent research experiences were also responsible for Natalie's beliefs about science content being too obscure at times. Natalie's beliefs about science remained very personal and affected her content knowledge, her other beliefs, and her teaching.

For June, her beliefs about science originated much earlier in her life. She was influenced by the time spent with her father exploring nature and his work place. June's science courses and experience in college did not impact her beliefs about science so she held on to her previous beliefs. But, June's beliefs about science also agreed with her role as a middle school teacher. She was able to correlate her beliefs about science with the ability level of her students. June's science beliefs became less personal and were used more for professional purposes.

Natalie and June's Confidence and Content Knowledge. Both teachers expressed deficiencies in their self-confidence and their content knowledge. For both teachers, their confidence directly affected their content knowledge and the new content they chose to incorporate into their existing content knowledge structures.

Natalie's self esteem issues grew from her feeling that she had "faked" her science content knowledge in high school and college. She had very few successes in science and was told by one instructor that she couldn't write, and this wrecked Natalie's self-confidence. To combat her inadequacies Natalie developed "tricks" to understand content and the more she understood, the more connections she made, and the more confidence she gained.

Much of June's lack of confidence stemmed from her undergraduate preparation in science teacher education. She felt like she did not take enough biology courses or have a strong biology foundation. Ironically though, instead of trying to gather as much content information as she could from the summer courses, June relied upon her previous learning practice of referring to others or text resources.

The following section discusses the course content presented in the two summer courses that Natalie and June incorporated into their own teaching of genetics.

<u>Course Content Represented in Natalie and June's Teaching</u>. The content from the two summer courses impacted Natalie and June's teaching of genetics--but in different ways. Natalie had taught genetics previously and added the pedagogical suggestions from the SBLC course that were consistent with her beliefs, but did not incorporate nor revisit the detailed content from the Biology Update 1 course into her teaching. However, she gained a confidence in knowing she could learn the detailed content. June had never taught genetics or heredity before and created a new unit using the content and pedagogical information obtained in the two summer courses. TABLE 7 and TABLE 8 detail, respectively, the content from the Biology Update 1 course and the Secondary Biology Curricula course that was incorporated into Natalie and June's teaching.

TABLE 7 Here

TABLE 8 Here

There was a considerable amount of genetics content from both courses that were not incorporated into the teachers' curriculum. The incorporation of content from the Biology Update 1 course was limited by several factors. First, Natalie and June's previous confidence levels, content knowledge, and beliefs hindered them from either learning detailed content, as in the case of June; or from teaching detailed science to their students, as in the case of Natalie. June was at a distinct disadvantage in the course because she did not have the background in biology nor the existing knowledge structures to make meaningful connections to her prior knowledge due to her amalgam of science courses. What resulted in June's teaching was a smattering of genetics content that was not presented in a way to build student understanding.

The second factor that limited the incorporation of Biology Update 1 content into the teachers' planning and teaching of genetics was the presentation order of the content. The content pertaining to Central Dogma was not presented in a sequential logical order and this created problems for the teachers who did not have strong background in the area. Natalie had said in an interview after the courses that she was able to fill holes in her content knowledge, but chose not to present the material to her students because it was too detailed. But June was not able to identify the holes in her knowledge about genetics because she did not have a foundation of information. Without a "mental map" of the content area, June could not see the relevance of the material or incorporate it into her knowledge base. Therefore, June's teaching of DNA concepts was quite brief and underdeveloped compared to the content presented in Biology Update 1.

Content from the SBLC course which focused on the teaching of mitosis was also affected by many of the same factors as the Biology Update 1 course. Of the two teachers, Natalie incorporated more suggestions and information from the SBLC course into her teaching. Again, a lack of a previous background and content knowledge in the area limited June in making connections between the new content and her prior knowledge. June though, did teach broad concepts as suggested by the course instructors, but this can be attributed to her level and lack of comfort with the content.

All of the factors presented thus far, have influenced the content these two teachers incorporated into their existing curriculum. The following section presents a model of secondary science curriculum influences based upon the cases of Natalie, June and the course content.

A Model of Secondary Curriculum Influences

The cases of Natalie, June, and the course content were helpful in creating a model of secondary curriculum influences that affect new content being incorporated into an existing curriculum. The model (see FIGURE 3) is shaped like a funnel with new content entering at the top and classroom teaching exiting the bottom. The funnel, which represents the teacher's thinking processes has two major components that the teacher must consider when incorporating new content: the teacher's internal influences and the teacher's external influences.

FIGURE 3 Here

Teacher's Internal Influences

As new content is "taken in" by the teacher, it will first have to pass through two majors filters before it can be incorporated into the teacher's content knowledge for teaching. The two filters, or layers through which the content must pass are: 1) a combination of past experiences, personal content knowledge, and confidence; and 2) the teachers existing beliefs about science, learning, and teaching science.

The first filter the "new" content must pass through consists of a combination of past experiences, personal content knowledge, and confidence. Every person has past experiences that influence their personal knowledge and confidence. For example, both Natalie and June did not have opportunities during their respective science teacher education programs to make connections between biology courses, thus affecting their content knowledge and resulting in a lack of self-confidence for both teachers. This first level is the most limiting of all the levels. By not having the "connections" in science before beginning to teach, the teachers may be limited to what new content they can incorporate into their personal content knowledge. If the "new" content presented does not have a place to "fit in" with the teacher's prior knowledge, or if the teacher does not have the confidence to learn the content, it will not pass on or "filter through" to the next level.

The second level or "filter" receives the "new" content that was incorporated into the teacher's personal content knowledge. The content passes through the teacher's belief system represented by the relationship between beliefs about science, learning, and teaching science. As the content enters this level, it travels around trying to find matches or inconsistencies with the established beliefs. Content that is inconsistent with the teacher's belief system stays at that level to possibly be considered at a later time. Content that matches the teacher's beliefs passes on to the next level to be considered as "new" content worthy of teaching.

It is possible that some new content which did not fit into the teacher's personal content knowledge correctly, still passed through to be considered and matched to the teacher's beliefs. Meaning, the teacher may make invalid connections with her prior knowledge, and that "new incorrect knowledge" is congruent with her beliefs and passes through as teachable content. As in the case of teachers required to teach a mandated curriculum, it is possible, but not represented in this study, that content not consistent with the teacher's beliefs may also pass through to the next level.

The third level with the teacher's internal influences is their teaching content knowledge. It is at this level that all "new" content that fit into the teacher's personal content knowledge and is in agreement with the teacher's beliefs is considered as content to be taught in the classroom. At this point the teacher must make planning decisions about what content to teach with respect to the her external influences.

External Influences

The teacher's external influences have been divided into three categories: student abilities, time constraints, and physical classroom limitations.

The teachers in this study identified students and their abilities as the first factor, after their own content knowledge that they consider when planning for science teaching. If the teacher thought her students could not handle the "new" content that she was considering to teach, the content would not pass to the next level.

If the teacher thought the "new" content was appropriate for students, she would then consider various time constraints in teaching the content. The teachers in this study identified the length of the class period as a limiting time factor. The average class period length for Natalie and June was 48 minutes and neither teacher's school had block scheduling. As June reported, this is hardly enough time to conduct an entire laboratory activity.

Time factors such as long term planning issues also influence the planning and incorporation of new content. Both of the teachers in this study had been teaching for three years or more and had an established curriculum. If new content is to be taught, some previously taught content must be cut because of the length of the school year. Also, creating and planning for new lessons was a limiting factor for what content filtered through to the next level. Both teachers also had in-school and outside school commitments which affected their planning time as well.

So, some new content that passes from the higher levels down to the "time constraints" level will not pass to the next level to be considered for teaching. Only new content that fits into the teacher's daily and long term planning schemes will filter through to the next level.

The final factors that influence "new" content to be taught are physical classroom limitations. Physical classroom constraints such as class size and room size can affect not only the content, but also, how the content is presented to the students. For example, student laboratory activities may become teacher led demonstrations because of a lack of materials for large classes. As mentioned, materials such as lab equipment and technology are also considered physical classroom limitations. For example, June learned advanced DNA spooling techniques in another summer course, but could not demonstrate this protocol for her students because she did not have the needed lab equipment. This example illustrates how content knowledge can pass through all previous levels yet never make it into a teacher's classroom practice because of a lack of equipment.

Finally, after passing through six different filters, "new content" has the opportunity to be expressed in the teacher's classroom teaching. But, once expressed, this new content is not stagnant--it can change in context and representation with the teacher's next opportunity to teach it. For example, both teachers changed their presentation of the genetics content when they felt it did not go well during the first hour. In the five minute passing period, each teacher revisited the four levels: teaching content knowledge, student abilities, time constraints, and physical classroom limitations. The result, even in that short time period, was a reworking and reteaching of the content in a new way.

This process--new content to classroom teaching--takes time. Obviously, the process begins with the introduction of new content. Whether immediately, or after revisiting the content, the new content begins it's journey into and through the teacher's schema. The process may be conscious or unconscious depending upon the teacher's personal content knowledge, confidence, and beliefs. But either way, the process becomes known to the teacher at the level of teaching and planning with the content. Here, the teacher must plan what to and how to teach the content. This planning and decision-making may occur weeks in advance, or when the bell rings to begin class. The content is filtered through factors such as student abilities, time constraints and physical classroom limitations and the result is the classroom teaching. Once taught, the content is again subject to change because of the teacher's external influences that came to light after teaching the content the first time.

Summary

This model represents the factors that influence secondary teachers when incorporating new content into their teaching. It considers the teacher's internal factors such as personal knowledge, confidence, beliefs and their teaching content knowledge; and the teacher's external factors such as student abilities, time constraints, and physical classroom limitations. This model is limited in scope due to the small number of teachers who participated in this study.

Significance

The two secondary science teachers in this study shared common deficits in their content knowledge as a result of their preservice science education. Neither teacher had the opportunity as an undergraduate science student, to make connections between important concepts within their discipline. Opportunities need to be made available for preservice secondary teachers to make these connections in their content area not only for their personal understandings, but for their pedagogical understandings as well. Too often, it is left to the secondary methods instructors to accomplish this task, but this is not the appropriate arena. Preservice teachers should have a strong content foundation before entering their methods classes so they may learn the pedagogical strategies necessary to teach their content. Courses that show interdisciplinary connections and intradisciplinary connections between science concepts would benefit these teachers greatly. With an adequate and "connected" content background, secondary teachers would be able to determine topics that are important and appropriate to teach their students. They would also be able to incorporate detailed or advanced content into their existing knowledge structures more easily than if they did not have the background knowledge.

Secondary teachers often are not aware of their existing beliefs about their content area or about teaching and learning. Teacher educators should be aware of the beliefs and help preservice and in-service teachers become aware of their beliefs by using content oriented activities that challenge the teachers to reflect and analyze their belief systems. By becoming aware of their own beliefs about teaching, learning, and their content area teachers would have the opportunity to create a better-informed and consistent practice.

Therefore, teacher education programs need to provide secondary teachers opportunities to build a strong content knowledge foundation during their undergraduate careers. This does not necessarily mean that preservice teachers need to take more content courses—quite the contrary. Preservice teachers need opportunities to explore the connectedness of concepts within and across disciplines. Teacher education programs also need to help teachers develop a strong system of beliefs that support an exemplary teaching practice. If teachers have a strong knowledge of content and a strong system of beliefs, they will be better able to incorporate into their teaching content appropriate for their students.

The model resulting from this study provides insights into the theoretical basis for increasing teachers' content knowledge understandings during and beyond undergraduate preparation. But, in addition, scientists and science teacher educators should develop courses or workshops that assist in-service teachers in updating their content knowledge structures—not just to update their curriculum, but to keep their personal content knowledge relevant. Also, encouraging teachers to explore their beliefs about science and science teaching would create a better-informed and validated practice.

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TABLE 1

Sequence of the Content: Biology Update 1

	Day							
Topic	1	2	3	4	5	6	7	8
Central Dogma		9	2	2		4		
Nucleotide structure		14						
DNA nucleotides		15				29		
RNA nucleotides		16						
Differences between DNA & RNA		10						
number of strands		11						
sugars		12						
bases		13						
Replication of DNA						11		1
Cell Cycle						1		2
M						2		3
Interphase--G1, S, G2						3		4
DNA structure			3			14		
5' to 3'			4			13		
antiparallel nature			5			12		
DNA helicase						16		
replication forks						15		
Okazaki pieces						20		
DNA polymerase I						17		
RNA primer						18		
RNA polymerase						19		
DNA polymerase II						21		
DNA ligase						22		
Transcription		7				5/23		
RNA structure		17						
Three forms of RNA		1						
rRNA		2						
3 sizes/s factor		3						
ribosomes		4						
mRNA		5						
tRNA		6						
RNA polymerase		8						
primary mRNA			6			6		
exons			7	3				
introns			8	4				
Translation						7/24		
protein structure		23						
polypeptides		24						
amino acids		18				8		
codons						26		
ribosomes								
reading frames						25		
tRNA						27		
anticodons						28		
condensation reactions		19						
inteins			1					
chaperone proteins						10		
Protein Function		22		1		9		
amino acid structure		20						
amino acid categories		21						

TABLE 2
The Relationship Between Natalie's Beliefs

Beliefs About Science	Beliefs About Learning	Beliefs About Teaching Science
• Science is the "world"	• Learning means using "real words" • Learning means making meaningful connections	• Stories help make content meaningful and interesting
• Science is curiosity with answers	• Learning is knowing where to look, not instantly recalling information • Learning occurs when you have a "need to know"	• Students should explore science concepts
• Scientists should focus on "bigger questions"	• Details are not important	• Content is a small part of teaching science • It is important to teach the "big picture" by simplifying the content
• Science has rules and is orderly • Science is logical and "sensical"		• Science topics are discreet and not interrelated • Science can be simplified by using "tricks"
	• Parroting is an important part of learning • A person needs confidence to learn • Need to write things down to understand	• Students have difficulties making connections • Kids need to know how to learn and have confidence to know they can

TABLE 3
Natalie's Teaching of Genetics

Concept	Detailed Explanation
DNA	All cells contain DNA Half of your DNA is from Mom, the other half from Dad Watson and Crick discovered DNA Shape is a twisted ladder—like sunshades for your windshield
Replication	When DNA makes a copy of itself DNA untwists and splits down the middle like a zipper Demonstrates with colored clothespins
DNA parts	Nucleotides—Adenine, thymine, cytosine, guanine are stuck together with hydrogen bonds; A always bonds to T; C always bonds to G.
Transcription	The process of making RNA; RNA nucleotides float in and attach to the unzipped DNA Demonstrates with colored clothespins
RNA nucleotides	Same as DNA nucleotides except A bonds to Uracil
RNA	Likes to stay single-stranded and then drifts off
Translation	A codon is a sequence of three RNA nucleotides The anticodon is on the tRNA that brings the amino acids
Mitosis	Cells contain DNA in the nucleus DNA copies itself The nucleus and cells pinches in half with equal numbers of chromosomes in each cell
Chromosomes	Are DNA We have 46 chromosomes in every cell
Meiosis	Phase II has 92 chromosomes after replication Sperm and egg need to reduce chromosome numbers
Crossing over	Process is like a blender that mixes up the chromosome parts
Mendelian Genetics	Mendels worked with Pea Plants; Laws of Segregation, dominance and recessive; homozygous and heterozygoes
Genotype	Are the genes and what the actual genes look like
Alleles	Are the letters you assign the genes
Punnett squares	Good trick for monohybrid crosses
Dihybrid crosses	FOIL method is a good trick for Independent Assortment
Incomplete Dominance	Called intermediate inheritance: cross a red flower with a white flower and get pink
Codominance	Called multiple alleles: blood and blood typing
Polygenic traits	Controlled by two or more genes responsible for a single trait: skin color
Pedigree charts	Used to determine recessive and dominant inherited disorders in humans
Chromosome alterations	Down syndrome, Klinefelter syndrome

TABLE 4
The Relationship Between June's Beliefs

Beliefs about Science	Beliefs about Learning	Beliefs about Teaching Science
• Science is rigorous and structured	• Students need to have structure • Content should be challenging	• Structure can be given by using lecture outlines • Students need research skills • Science should be challenging and difficult • Students need a realistic view of science
• Science is fun and exciting • Science is about being curious and exploration	• Content needs to be simplified and without details • Science needs to be relevant for learning • Learning is important for future needs	• Need to create an interest in science for all students • Creative activities make science interesting • Presenting new content allows exploration and interest • Stories and analogies make science relevant
	• Students have a variety of learning styles • Students can learn details--it would take time • Answers can be found by asking people and looking in books	• Need to present content in many different ways for students • Students' abilities limit the activities and content that can be covered • Peers and reference books are important sources of knowledge

TABLE 5
June's Teaching of Genetics

Unit	Concept	Detail/Explanation
Cell	DNA	• Makes up chromosomes • Located in cells' nucleus • Responsible for body functioning and characteristics
Heredity	Mitosis	• Cells divide so organisms can grow • New cells need DNA • DNA has to reproduce so new cells will have identical copies • DNA is wound up in chromosomes
	Genes	• Found on chromosomes • Represented as alleles for characteristics or traits
	Incomplete Dominance	• Results in a third trait because neither parent is dominant
	Dominance	• Dominant traits are stronger and mask recessive traits
	Homozygous	• dominant TT; recessive tt • "homo" means same
	Heterozygous	• Tt • "hetero" means different or hybrid
	Genotype	• what genes are present
	Phenotype	• What genes are expressed
	Alleles	• A capital letter symbolizes a dominant gene • A lower case letter symbolizes the recessive gene • "T" was an allele that represented a dominant trait for an organism • "t" was an allele that represented a recessive trait for an organism • Activity/Worksheets--probability and inherited traits
	Meiosis	• Diploid--a cell or organism in which each chromosome is present in duplicate (2 of each) • Haploid--a cell in which there is one of each chromosome, produced during meiosis of a diploid • A type of cell division that produces sex cells • Gametes = Sex cells, eggs & sperm • Four gametes are made • Zygote--a fertilized egg
	Punnett Squares	• Genes for parents are put outside the square • There are 46 chromosomes in normal human cells
	Dominance & Recessiveness	• Worksheet/Activity
	Pedigree Charts	• Circles symbolize females; squares symbolize males; filled figures expressed the trait; clear or empty figures did not express the trait • Worksheet
	DNA & Chromosomes	• Karyotype--a picture of chromosomes which are replicated, visible, and in the "X" structure • Think of chromosomes as a telephone cord that has been twisted and knotted • Keep unwinding and get the ladder and the A, T, G, and C, the nitrogenous bases. Each one pairs with another and creates a step in the ladder • Coil it all back up and it is a chromosome
	Triplet code	• Every three letters means something • It is like a secret language which has to be decoded to understand the message • The body decodes the letters very quickly and brings an amino acid which are the building blocks of proteins--they help you grow, repair your tissue, and produce different chemicals.

TABLE 6
Natalie and June Compared

<table>
<tr><th>Factor</th><th>Natalie</th><th>June</th></tr>
<tr><td>Confidence and Content Knowledge</td><td>• Low self-esteem
• Felt that she had "faked" science knowledge in the past
• Developed "tricks" to understand content</td><td>• Little confidence due to undergrad science preparation
• Relied upon asking others instead of learning for herself</td></tr>
<tr><td rowspan="2">Past Science Experiences</td><td colspan="2">• Entered community college prior to four-year institution
• Health related major prior to secondary education
• Took an amalgam of biology courses in no particular order</td></tr>
<tr><td>• Natalie changed major late
• Struggled with science content
• Avoided details</td><td>• June took many independent study biology courses—"the easy way"
• Spent time exploring science in non-academic settings</td></tr>
<tr><td>Beliefs about Science</td><td colspan="2">• Science is about being curious
• Science has an inherent structure
• Science is "cool" and fun</td></tr>
<tr><td>Beliefs about Learning</td><td colspan="2">• Content must be relevant to learn
• One will learn when there is a "need to know"
• Content should be simplified to ensure students learn and have a good attitude toward science
• One can learn by referring to outside resources</td></tr>
<tr><td>Beliefs about Teaching Science</td><td colspan="2">• Students should be allowed to explore science concepts
• Students' abilities limit their understanding
• Stories and analogies should be used to make science meaningful</td></tr>
</table>

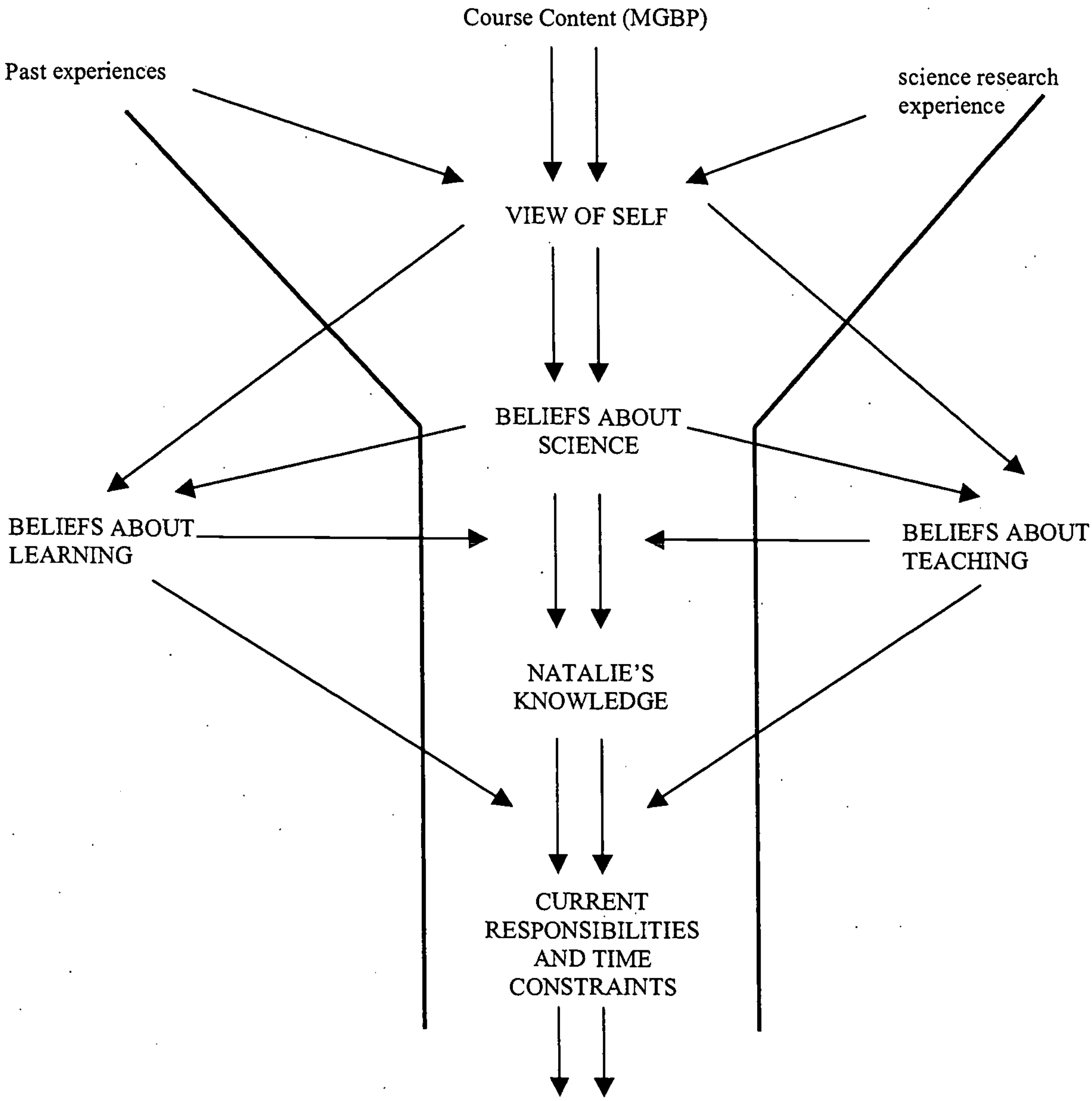
TABLE 7

Biology Update 1 Content in Natalie and June's Teaching (√ = present; √* = present but simplified)

Topic	Natalie's Teaching	June's Teaching
Central Dogma		
Nucleotide structure		
DNA nucleotides	√*	
RNA nucleotides		
Differences between DNA & RNA		
number of strands	√	DNA only
sugars		
bases	√	DNA only
Replication of DNA	√*	
Cell Cycle		
M		
Interphase--G1, S, G2		
DNA structure	√*	
5' to 3'		
antiparallel nature		
DNA helicase		
replication forks		
Okazaki pieces		
DNA polymerase I		
RNA primer		
RNA polymerase		
DNA polymerase II		
DNA ligase		
Transcription	√	
RNA structure	√*	
Three forms of RNA		
rRNA		
3 sizes/s factor		
ribosomes		
mRNA	√	
tRNA		
RNA polymerase		
primary mRNA		
exons		
introns		
Translation	√	
protein structure		√*
polypeptides		
amino acids	√	√
codons	√	√*
ribosomes	√	
reading frames		
tRNA	√	
anticodons	√	
condensation reactions		
inteins		
chaperone proteins		√
Protein Function		
amino acid structure		
amino acid categories		

TABLE 8
SBLC Content in Natalie and June's Teaching (√ = present; √* = present but simplified)

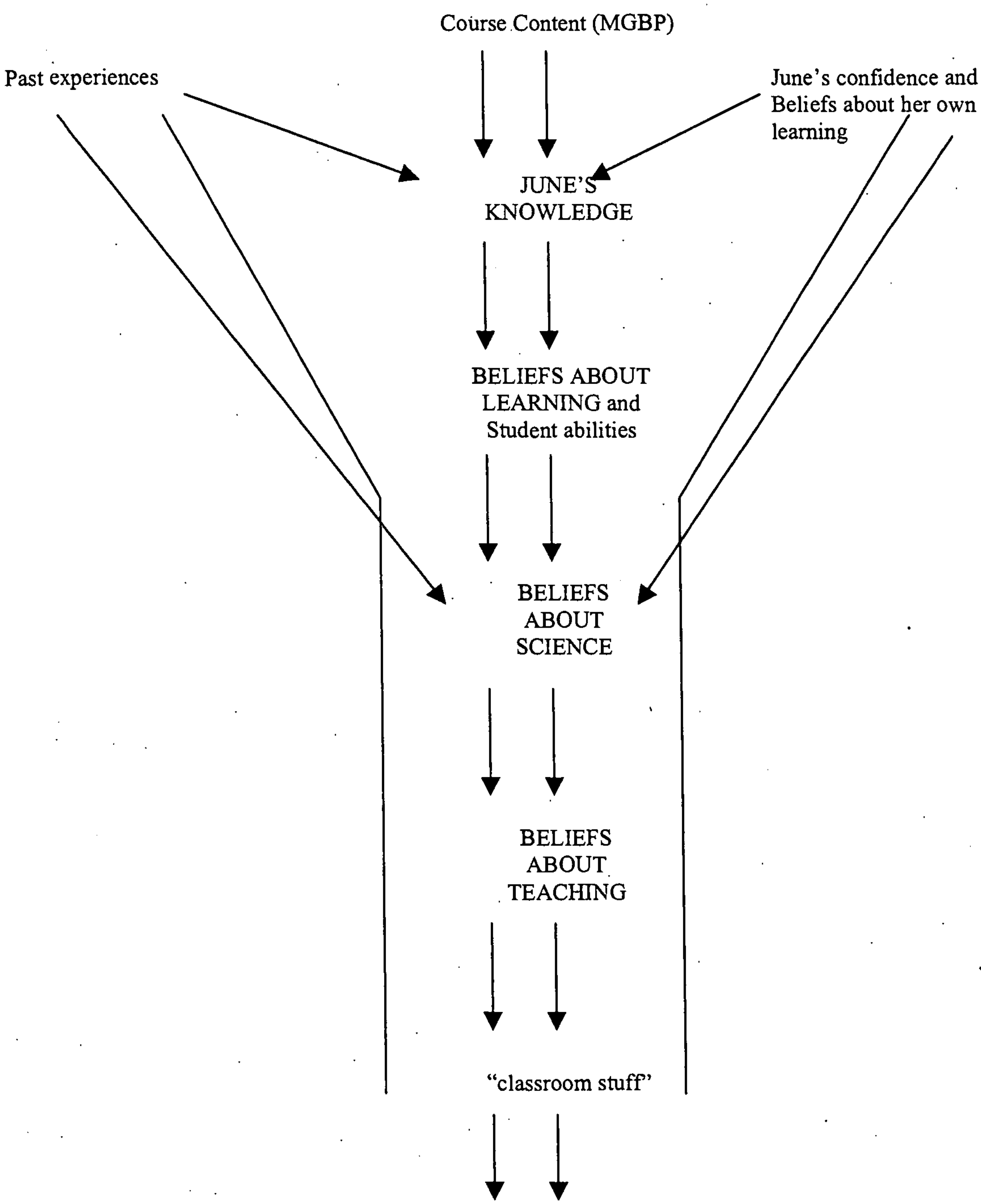
Topic	Natalie's Teaching	June's Teaching
Chromosomes		√
made of tightly wound DNA		√
occur in pairs called homologous chromosomes		
cells with both homologues are called diploid		√*
cells with one of the pair are called haploid		√*
human body cells—diploid (46)	√*	√
human gamete cells—haploid (23)	√*	√
Mitosis	√*	√*
increase number of cells	√	√
cell divides into 2 identical cells	√	√
replication	√*	√*
continuous—four phases		
prophase	√*	
metaphase	√*	
anaphase	√*	
telophase	√*	
cytokinesis	√*	
Meiosis	√*	√*
reduces number of chromosomes by half	√	√
involved in sexual reproduction	√	√
8 phases	√*	
replication, centromere		
meiosis I	√*	
2 daughter cells (23 x 2 each)	√*	
crossing over	√*	
meiosis II	√*	
4 haploid daughter cells each	√*	√*
genetically different		
Mendelian Genetics	√	
dominance and recessiveness	√	√
segregation	√	
independent assortment	√*	
Genetic Crosses	√	√
alleles	√	√
gene		√
genotype	√*	√
phenotype	√*	
homozygous	√	√
heterozygous	√	√
monohybrid cross	√	√*
dihybrid cross	√	
Punnett square	√	√



NATALIE'S GENETICS TEACHING

- Simplified content
- Content lacked many details
- Mainly lecture presentation
- Taught "tricks" to learn content
- Had students "parrot" or repeat
- Used stories and analogies
- Used demonstrations
- Taught without planned notes

FIGURE 1. Diagram of Natalie's Curriculum Influences



JUNE'S GENETICS TEACHING

- Simplified content
- Focused more on inheritance, less on mitosis and central dogma
- Used analogies and stories
- Had many activities in addition to class notes

FIGURE 2. Diagram of June's Curriculum Influences

Content Construction
J.M. Grier, April 2003

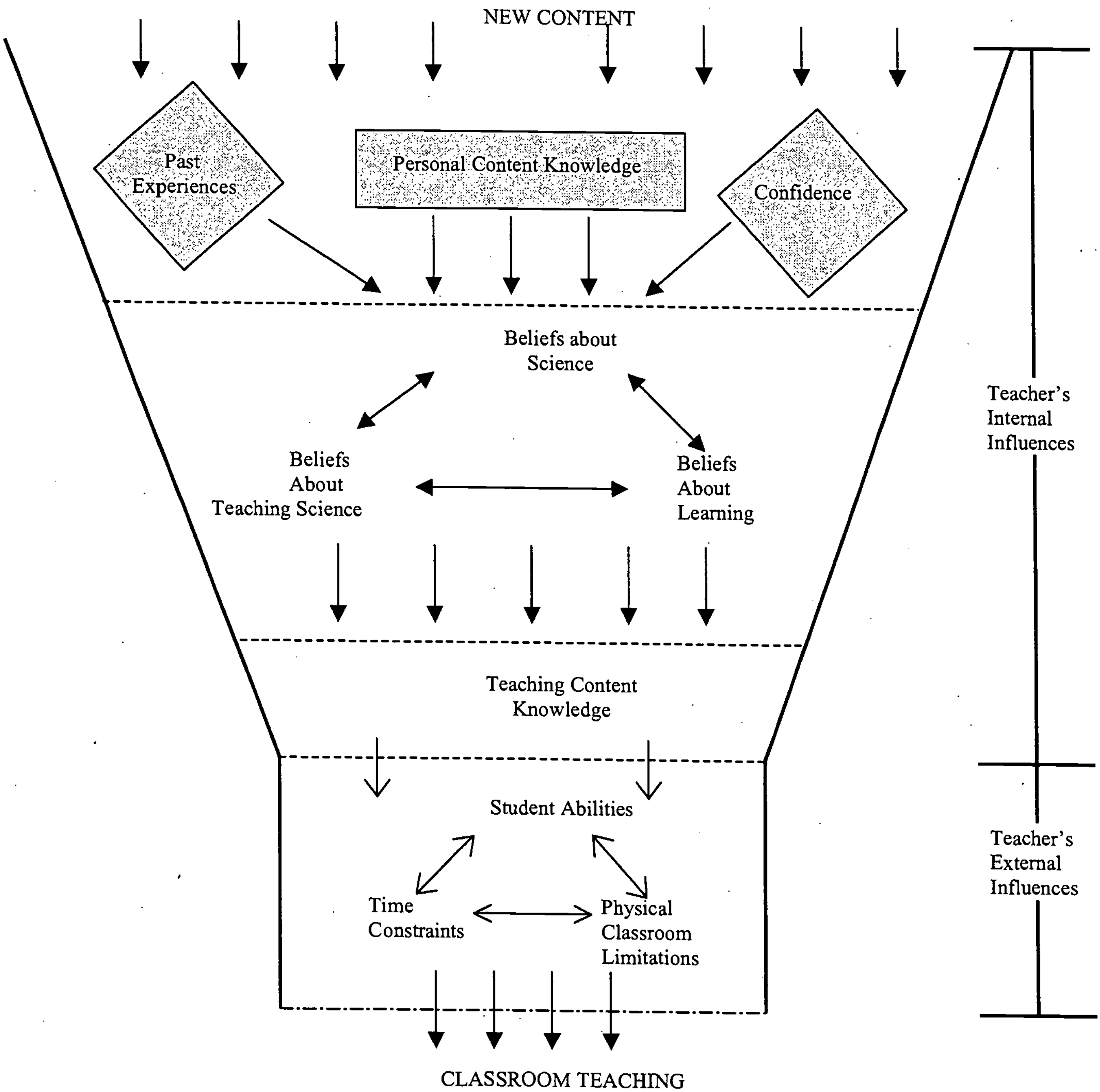


FIGURE 3. Secondary Curriculum Influences that Affect Incorporating New Content into an Existing Curriculum

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